

Non-thermal component of galaxy clusters

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Abstract

Deep radio observations of galaxy clusters have revealed the existence of diffuse radio sources related to the presence of relativistic electrons and weak magnetic fields in the intra-cluster volume. Intra-cluster relativistic electrons can also give rise to hard X-ray emission through Compton scattering of CMB photons. I will show the importance of combining galaxy cluster observations by new-generation radio and X-ray instruments such as LOFAR and IXO.

A deeper knowledge of the non-thermal cluster component will allow to test current cluster formation scenario and to better constrain the physics of large scale structure evolution.

Introduction

Galaxy clusters are made of:

- Dark matter
dominant form of mass
[$\sim 80\% M_{\text{cluster}}$]
- Hot and tenuous intra-cluster medium (ICM)
dominant baryonic component
[$\sim 15\% M_{\text{cluster}}$]
- Galaxies
- Non-thermal intra-cluster component

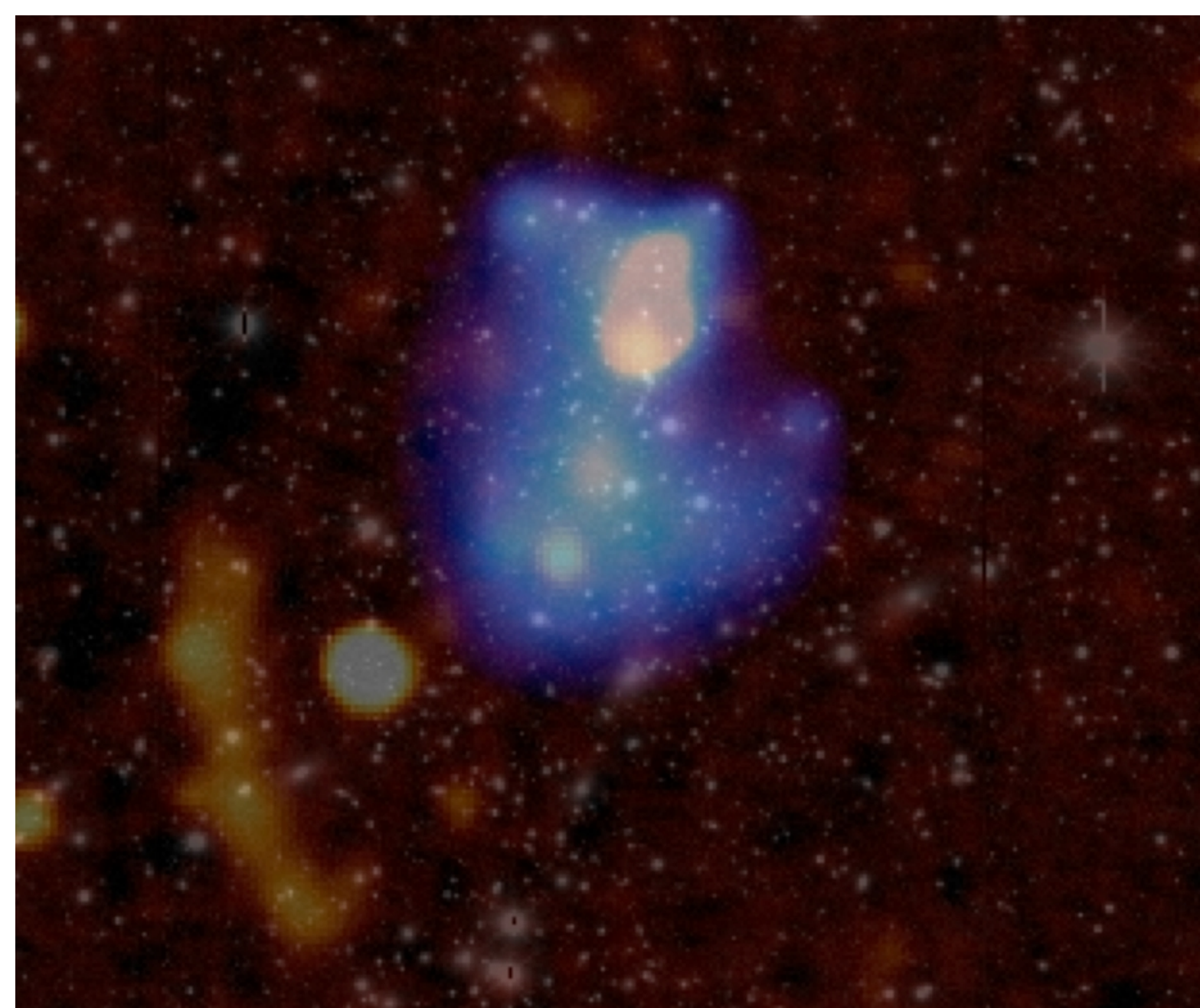


Figure 1 - The galaxy cluster Abell 521 observed in optical (ESO, white), X-rays (Chandra, blue) and radio (VLA, brown)
[Adapted from Ferrari+ 03, 06]

Galaxy clusters form through merging of less massive systems:

- Evidence from X-ray and optical observations
- In agreement with the expectation of the hierarchical scenario of structure formation emerging from the concordant cosmological model

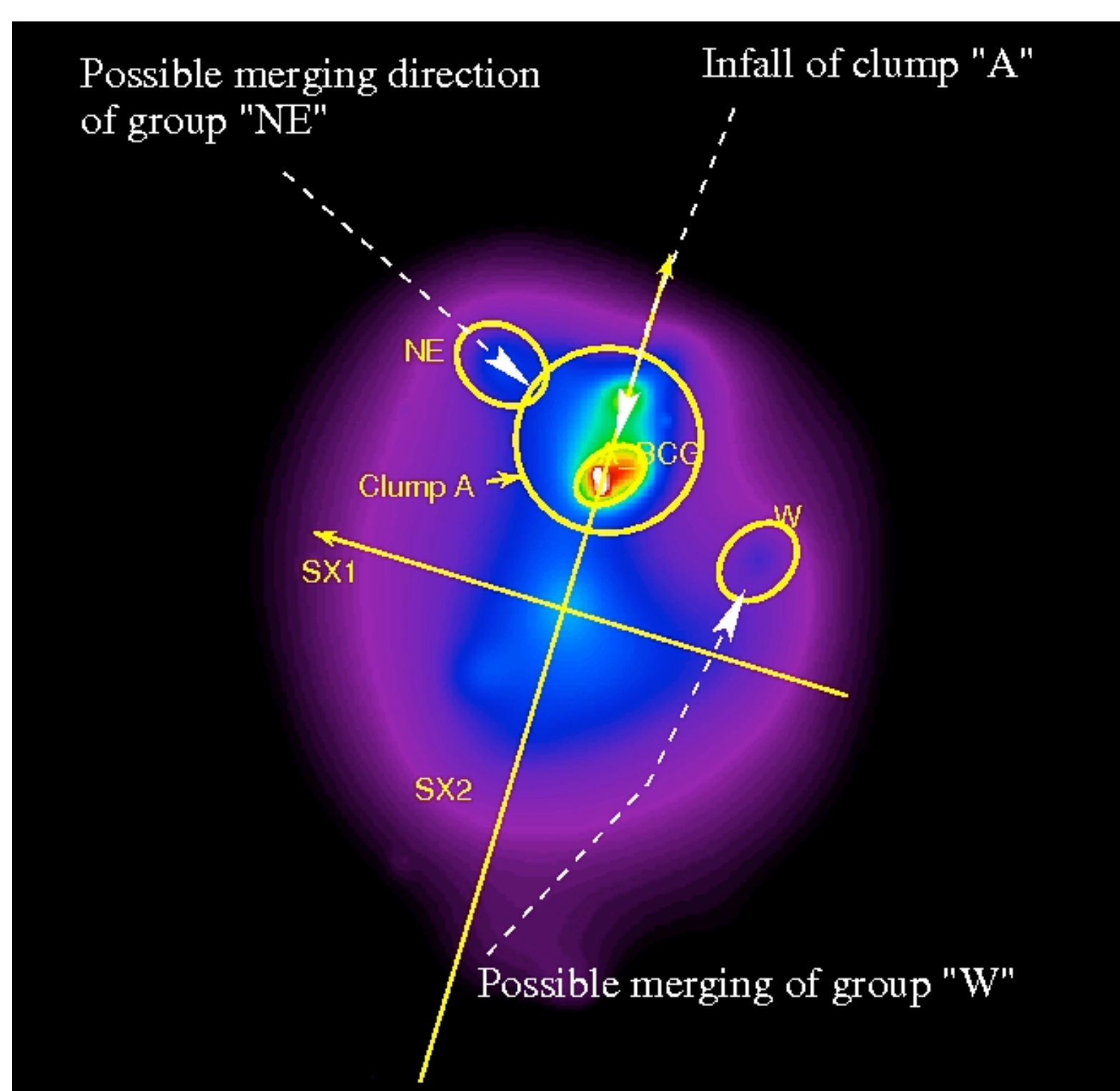


Figure 2 - Multiple merging scenario for Abell 521 reconstructed by comparing optical and X-ray observations of the cluster
[From Ferrari+ 06]

Non-thermal intra-cluster component

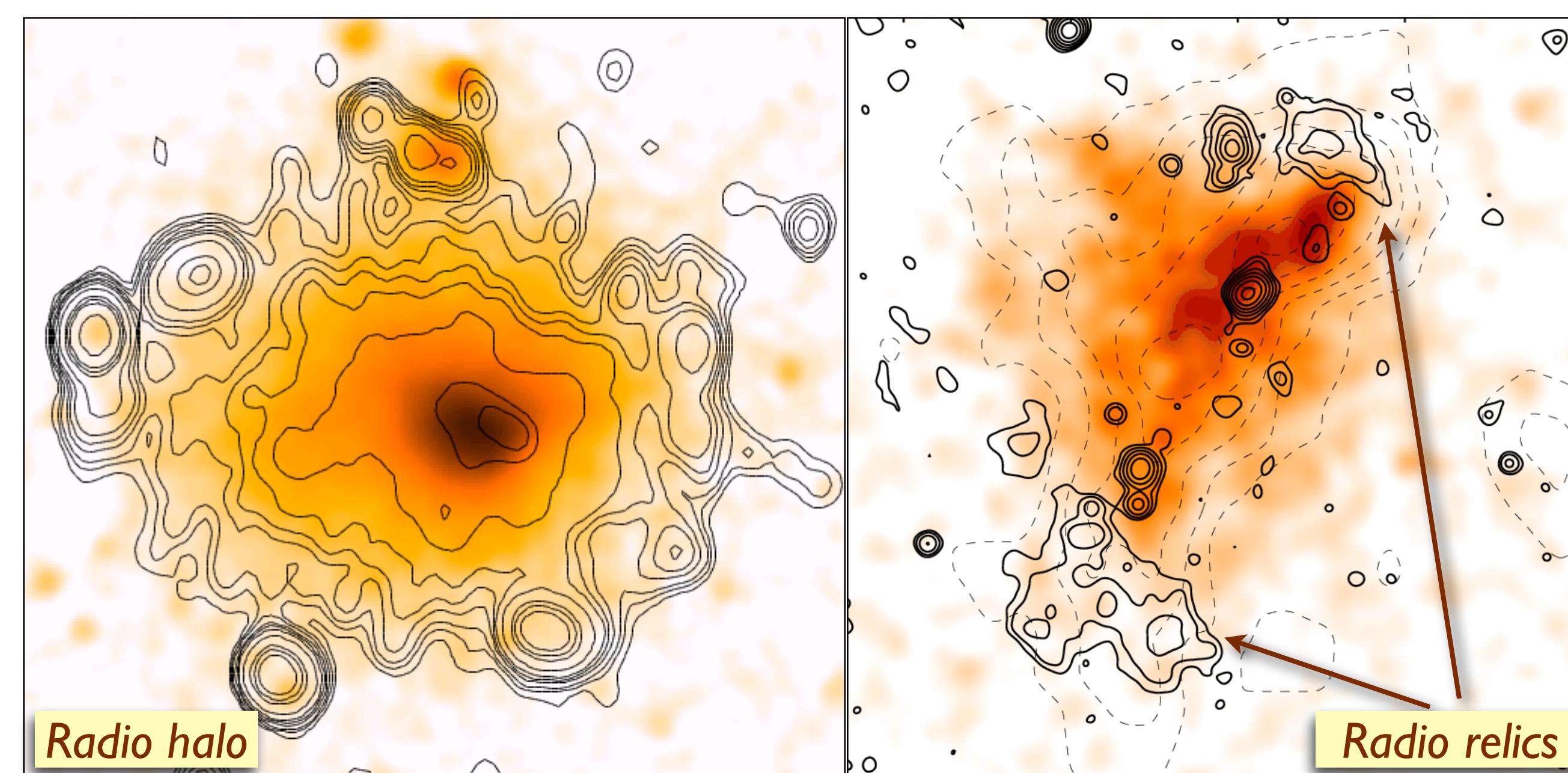


Figure 3 - Radio contours overlaid on the X-ray image of Abell 2163 (left) and ZwCl 2341.1+0000 (right)
[Left: adapted from Feretti+ 01, Bourdin+ in prep. - Right: van Weeren+ 09]

- Deep radio observations of the sky have revealed the presence of extended (~ 1 Mpc) radio sources in about 60 galaxy clusters [Ferrari+ 08 and refs. therein]
- Diffuse radio emission indicates the presence of intra-cluster relativistic electrons ($\gamma \gg 1000$) and weak magnetic fields ($\sim \mu\text{Gauss}$)
- Extended radio sources permeating the central volume of the cluster are usually referred as «radio halos» [left panel of Figure 3]
- Elongated radio sources in the cluster periphery are known as «radio relics» [right panel of Figure 3]
- Both radio halos and radio relics are characterized by steep synchrotron spectra [left panel of Figure 4], indicative of ageing of relativistic particles
- Up to now diffuse intra-cluster radio sources have been detected only in merging galaxy clusters. Their radio power strongly correlates with the X-ray luminosity of the host clusters [right panel of Figure 4]

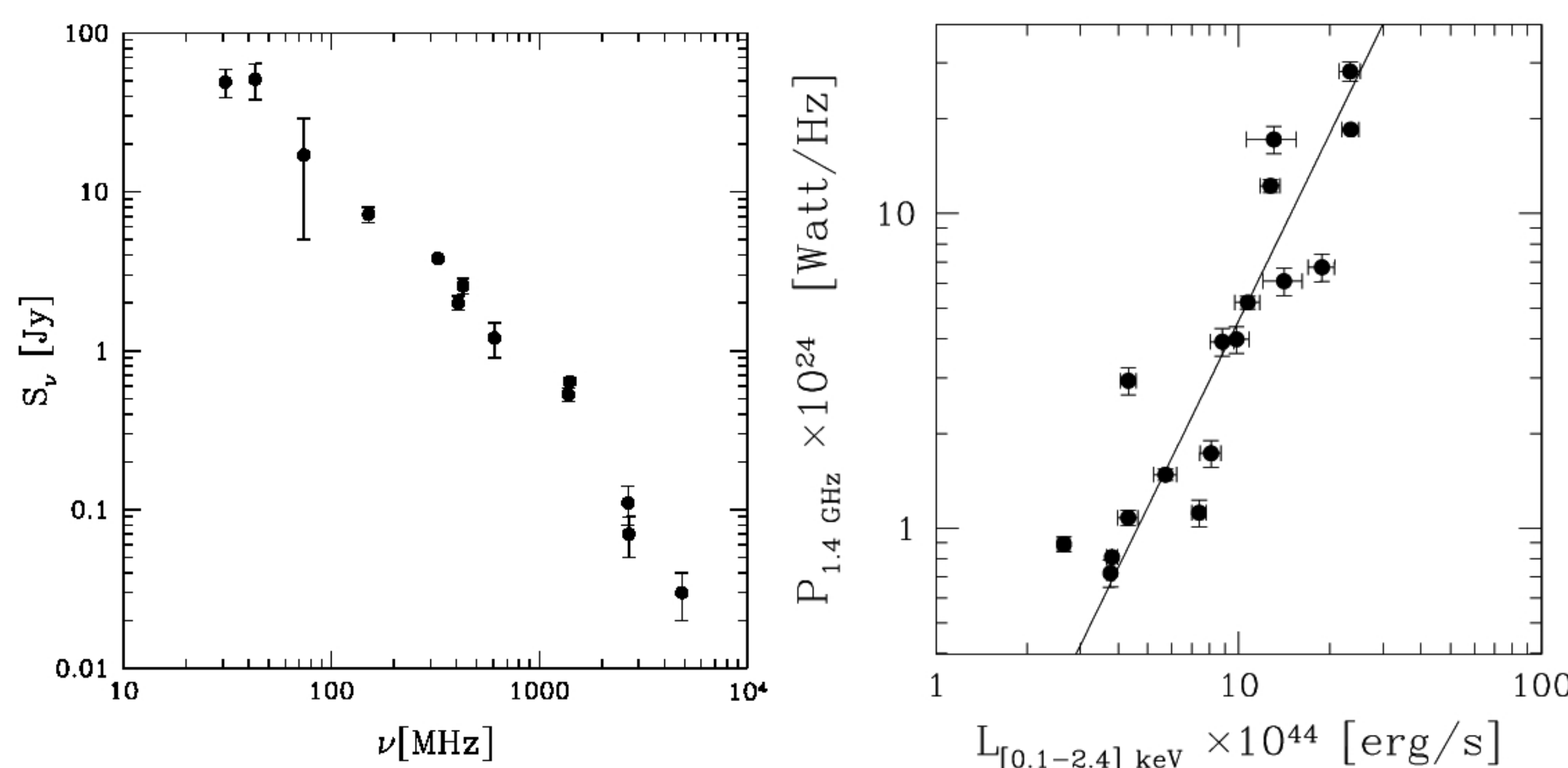


Figure 4 - Spectrum of the radio halo in the Coma cluster (left). Radio power at 1.4 GHz of radio halos vs. cluster X-ray luminosity
[Adapted from Thierbach+ 03 (left) and Cassano+ 06 (right)]

Open questions

- Physical mechanisms responsible for relativistic electron acceleration
 - Primary models: shocks / turbulence related to cluster mergers; favored by current observational results [e.g. Brunetti+ 01]
 - Secondary models: hadronic collisions between relativistic protons and ions of the ICM; gamma-ray emission from clusters is predicted [e.g. Dennison 80]
 - Hybrid models: primary + secondary models [e.g. Pfrommer+ 07]
- Intensity of intra-cluster magnetic fields [e.g. Govoni & Feretti 04]
 - Faraday rotation measures of polarized radio sources within / behind clusters - current measurements: $1-10 \mu\text{G}$
 - Inverse Compton scattering of CMB photons giving rise to hard X-ray emission - current measurements: $0.1-0.3 \mu\text{G}$
 - Energy equipartition assumption between intra-cluster cosmic rays (CR) and magnetic fields - current measurements: $0.1-0.3 \mu\text{G}$
- Non-thermal component and physical properties of clusters
 - Effects of the non-thermal component on the thermo-dynamical evolution of galaxy clusters [e.g. Sharma+ 09]
 - Pressure provided by the non-thermal component [e.g. Myers+ 10]

Need of:

- Statistical samples of halos / relics \rightarrow LOFAR surveys [P.I. Röttgering]
 - Low frequency (<200 MHz) observations are optimal for the detection of steep spectrum radio sources [left panel of Figure 4]
 - Hundreds of halo / relic detections expected [e.g. Cassano+ 10]
- Complementary multi-frequency surveys (Gamma- and X-rays, sub-mm, optical) for:
 - Cluster detection and physical characterization (mass, dyn. state) [\rightarrow Are newly detected diffuse radio sources associated to clusters? Are diffuse radio sources really hosted only by the most massive merging clusters?]
 - Temperature, pressure, entropy and metallicity maps of the ICM [\rightarrow Interplay between the thermal and non-thermal cluster physics]
 - Analysis of the hard X-ray and Gamma-ray flux from galaxy clusters [\rightarrow Measure of intra-cluster magnetic fields & constraints on particle energy density and acceleration]

Acknowledgments

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